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Comment on "Regression Rates of Metalized Hybrid Fuel Systems"

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THE approach employed by the authors to evaluate the parameter B requires many assumptions about details of the reaction process and about the reaction mechanism in general, e.g., thermodynamic equilibrium at the wall, as well as a relatively elaborate computer calculation. Some time ago, during the course of our own investigation of hybrid combustion, the writer and his colleagues (then at United Technology Center) also gave serious consideration to such an approach. We found, as do the authors, that the value obtained for B is highly sensitive to the assumed wall temperature. This problem arises primarily because the total enthalpy at the wall, h_w, includes a sum of products of mole fractions and the corresponding heats of formation, and the latter generally are large relative to the sensible enthalpy. Therefore, small changes in the composition at the wall correspond to large changes in h_w, and an accurate evaluation of the latter requires a precise description of the reaction process. Moreover, the computational problem is compounded by the fact that the calculation of h_w usually involves small differences of large numbers. Owing to these difficulties, which are largely computational in nature and do not necessarily reflect inherent features of the actual combustion mechanism, the results can be misleading. Also, in view of the ultimate need for arbitrarily choosing the wall temperature, one may question whether a relatively complicated numerical calculation is really warranted.

An alternative approach is to replace the assumptions concerning details of the reaction process at the interface with another assumption that certainly is at least equally valid: that reactions between the flame zone and the interface may be neglected. It is then possible to represent B in terms of the sensible enthalpy difference between the flame and the wall, if the Reynolds analogy is appropriately modified to replace the enthalpy at the boundary-layer edge with that at the flame.[1–3] [The Colburn analogy and Reynolds analogy are essentially identical, and both are based on the total enthalpy difference across the entire boundary layer.[4] The authors have used the flame enthalpy without correcting Eq. (1). Such a correction, which is needed to make the treatment strictly consistent, would increase their values of B by approximately a factor of 2.]

The use of the sensible enthalpy difference greatly simplifies the calculation of B and eliminates the high sensitivity to an assumed wall temperature. Comparisons between an analytical treatment using this approach and data for several metalized and nonmetalized propellants show good agreement over a wide range of operating conditions when a single value, 700°K, is always assigned to the wall temperature.[5] Increasing the assumed wall temperature by 43% to 1000°K would reduce the predicted regression rates by only about 8%.

It should be noted that the data for these comparisons were obtained in motors rather than in a slab burner. In contrast to the results in this paper, our experiments were performed at pressures greater than 150 psi and showed a substantial effect of metal loading even when the latter is less than 50%. However, at lower pressures and at higher mass fluxes, we have observed the regression rate reduction measured by the authors. In these regimes, the simple heat-transfer theory is inadequate, as they have noted.

In submitting these comments, the writer does not wish to detract in any way from the authors' accomplishment; they are to be commended for presenting the most comprehensive data available for the propellant systems investigated in the paper. However, it is felt that the preceding points deserve consideration in examining the relationships between the theory and experimental results.

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An Alternate Analysis of Momentum Deposition in the Wake of a Re-Entry Vehicle

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REFERENCE 1 estimates the effects of ablation on the momentum introduced into the wake of a re-entering vehicle. In Ref. 1, the heat of sublimation is employed to describe the properties of the ablating vehicle. The behavior of more complex, commonly used materials is usually characterized by the heat of ablation defined for experimental reasons in terms of the nonblowing heating rate. It is the purpose of this paper to provide an analysis in which the material behavior is represented by this parameter. The present

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